Eliciting thinking skills with inquiry maps in CLE

Book Section

ELICITING THINKING SKILLS WITH INQUIRY MAPS IN CLE

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Abstract

The first aim of this chapter is to present the contributions drawn from the study exploring the use of inquiry maps in academic research for eliciting thinking skills. The second objective of this work is to highlight the potential collaborative learning environments (CLEs) have to enable students to learn different mapping techniques and to help them share ways in which they can apply inquiry maps to elaborate their scientific projects. While the study is informed by qualitative research methodology, it employs quantitative data to describe the fieldwork: an online course, which was organized by the author. The participants were lecturers and research students from different countries: Brazil, United Kingdom and Portugal. Findings indicate six kinds of inquiry maps that can be applied in academic research and may contribute to developing thinking skills such as, critical thinking, content thinking and creative thinking.

1. Introduction: Inquiry Maps for Academic Research in CLE.

Information literacy is a vital skill for research students in the digital age. Students need to know how to locate, evaluate and use information effectively in their academic courses and in their workplace. They also have to be able to structure the stages of their investigation, and integrate theory and data. Mapping software tools can help them construct meaning from the information selected through search engines, news feeds, course content and research literature.

Knowledge Cartography (Okada, Buckingham Shum & Sherborne, 2008) is one of the most promising resources for these challenges. Through knowledge maps, learners can integrate information with graphical representations of key components and connections. Concept mapping helps students represent and visualize concepts that they know and do not know (Cañas & Novak, 2008). Mapmaking scaffolds different forms of reasoning about arguments (Van Gelder, 2002), engaging students in meaningful learning (Novak, 1998) and critical thinking (Jonassen, 2000; Jonassen, Beissner, & Yacci, 1993).

This chapter presents how mapping techniques and software tools (e.g. Cmap Tools, Nestor Web Cartographer, Compendium and Freemind) can be used by PhD students to connect knowledge during their research projects. In this study, we denominate "inquiry maps" as a range of six kinds of knowledge maps for developing academic research:

1. Research map for designing a research project.
2. Reference map for collecting references in the literature.
3. Reading map for selecting key ideas of papers´ content.
4. Theory map for organising key concepts and definitions from the literature.
5. Fieldwork map for structuring key data from a corpus of documents.
6. Writing map for integrating key arguments for an essay.

The term “inquiry maps” is used in this work to denote graphical representations of knowledge during a research process. The thesis of this study is that these inquiry maps play an important role for eliciting thinking skills by helping researchers identify, connect and interpret key issues, ideas, concepts, data and arguments. Knowledge mapping software, in which learners can construct, examine and transform their thinking, acts as mediating inquiry tools. These tools for representational guidance mediate learning interactions and thinking by providing learners with means to represent emerging knowledge graphically (Suthers, 2003; Roschelle, 1994).

This work also describes a collaborative learning environment (CLE) that employed inquiry maps for research students and educators to learn software tools and apply mapping techniques to develop their research projects. Another purpose for this CLE was engaging participants in sharing their inquiry maps and improving their ways of mapping with peers. These collaborative interactions and feedback about the process of inquiry mapping might lead them to develop thinking skills and improve their inquiry projects. In the CLE analysed in this study, we used three kinds of maps application:

1. Personal map for participants introducing themselves in the CLE
2. Learning path map for participants accessing and visualising activities and content.
3. Portifolio map for participants accessing and visualising their individual and collective productions.

In order to explain each of the above map models, examples were selected and analysed from a CLE created during an online course – *Using Software for Qualitative Research*. This course was offered at the University of PUC-SP in Brazil from 2004 to 2005. The number of participants was 35 research students and 20 lecturers from Brazil, Portugal and The United Kingdom.

This study, thus, aims to address the following research questions:

- What are the contributions of applying inquiry maps to academic projects?
- What are the benefits of using CLEs with diverse mapping techniques for participants?
- What are the challenges of using inquiry maps to elicit thinking skills?

2. Theoretical Principles: Thinking Skills through Inquiry Maps.

The contemporary critical thinking movement, which started in the 60s as an antidote to reproductive and passive learning, argues that learners should not acquire knowledge just by memorising and repeating what texts and experts say. The simple process of “copying and pasting information” does not mean acquiring knowledge. Thus, a significant construction of knowledge involves interpretation, sensemaking and critical thinking (Jonassen, 2000).

At the same time, inquiry-based learning became an important approach to engage students in research projects. Its core purpose is to help learners act as critical thinkers for managing their own investigation rather than act as passive receivers of content. Freire (1967) points out that critical thinking is an important skill not only for apprehending meaning, knowledge and truth of the reality, but also for making decisions, implementing actions and improving results provoking changes. To be critical means thinking-acting-reflecting in order to make improvements (praxis). It also involves reading and writing the world - not only identifying words, but also understanding their meanings, reasons, consequences, aims, context, references and evidence.

Inquiry-based learning has been considered a complex process. Teachers need to provide learners with strategies, tools and guidance by helping them apply what they know and also new knowledge in problem-based activities (Edelson, 1997; Hmelo-Silver, Duncan & Chinn,

2007). Inquiry-based learning requires students to develop several skills. Therefore in order to construct knowledge during their investigation, students must be able to:

- Formulate key questions.
- Select relevant information to address the main issues.
- Identify new knowledge and make sense in order to construct meanings.
- Choose appropriate methods of inquiry.
- Develop possible solutions and draw conclusions.
- Get feedback and points of view to evaluate the process and products.

Academic research is also framed as ongoing and complex process of raising significant questions, integrating relevant information and generating acceptable lines of reasoning grounded on scientific assumptions and bodies of knowledge (Veerman, 2003). A key capability to foster in research students to tackle this challenge is the ability (1) to map information, ideas and arguments; and (2) to manage the rich connections that emerge between them using a range of cartographic techniques. (Okada & Buckingham Shum, 2006).

Cartographic representation is one of the most ancient forms of communication and tools for thinking (Harley & Woodward, 1987). Map-making, which pre-dates both numbering systems and writing, has been used to represent not only geographic space, but knowledge areas as well. The earliest concept maps were found during Middle age to describe the nature of elements, concepts and meanings (Edson, 1997). During the early modern period, concept maps were used to organise and classify different areas of knowledge, curriculum and libraries.

However, the digitalisation of cartography and the widespread use of computer have led to rapid manipulation, transformation and reconstruction of graphical representations than ever before. The diversity of software tools (eg. Cmap Tools, Freemind, Nestor Web Cartographer and Compendium), mapping techniques and tutorials available on the internet, allow individuals or groups to create high quality maps for representing and sharing knowledge. Knowledge cartography as a strategy *to capture, mediate, and improve constructive discourse* presents diverse mapping techniques and software tools to map knowledge (see Table 1), which can be applied to learning and research (Okada, Buckingham Shum and Sherborne, 2008).

Mapping techniques	Aims	Freeware Tools
Concept Map (Novak, 1989)	to organise concepts	Cmap Tools
Mind Map (Buzan, 1993)	to generate ideas	Freemind
Web Map (Okada & Zeiliger, 2003)	to collect web resources	Nestor Web Cartographer
Issue Map (Conklin, 2005);	to structure discussions	Compendium
Argument Map (Van Gelder 2002)	to develop argumentation	Compendium

Table1. Genres of knowledge map Knowledge Cartography

Well-designed maps are flexible sources of communication and tools for thinking because they help people use their minds to identify key elements and connections that may otherwise not be noticed without graphical visualisation (Dodge and Kitchin, 2001).

> *Weaving connections between nodes in the network is the most flexible way to bring ideas and information into locally coherent relationships with each other, knowing that there is always another viewpoint on the validity of these patterns.* (Okada Buckingham Shum and Sherborne, 2008:ii)

Interpreting knowledge from maps help students visualise and identify important structures or steps around problem-solution such as: generalisation, enumerations, sequence, classification and, compare and contrast (Cook and Mayer, 1988). McTighe(1992: 183) points out that graphical representations "have proven to be effective tools for enhancing thinking and promoting meaningful learning by helping teachers and students to organise information, generate many ideas, represent abstract concepts, illustrate relationships, relate new information to prior knowledge, store and retrieve information, and assess thinking and learning".

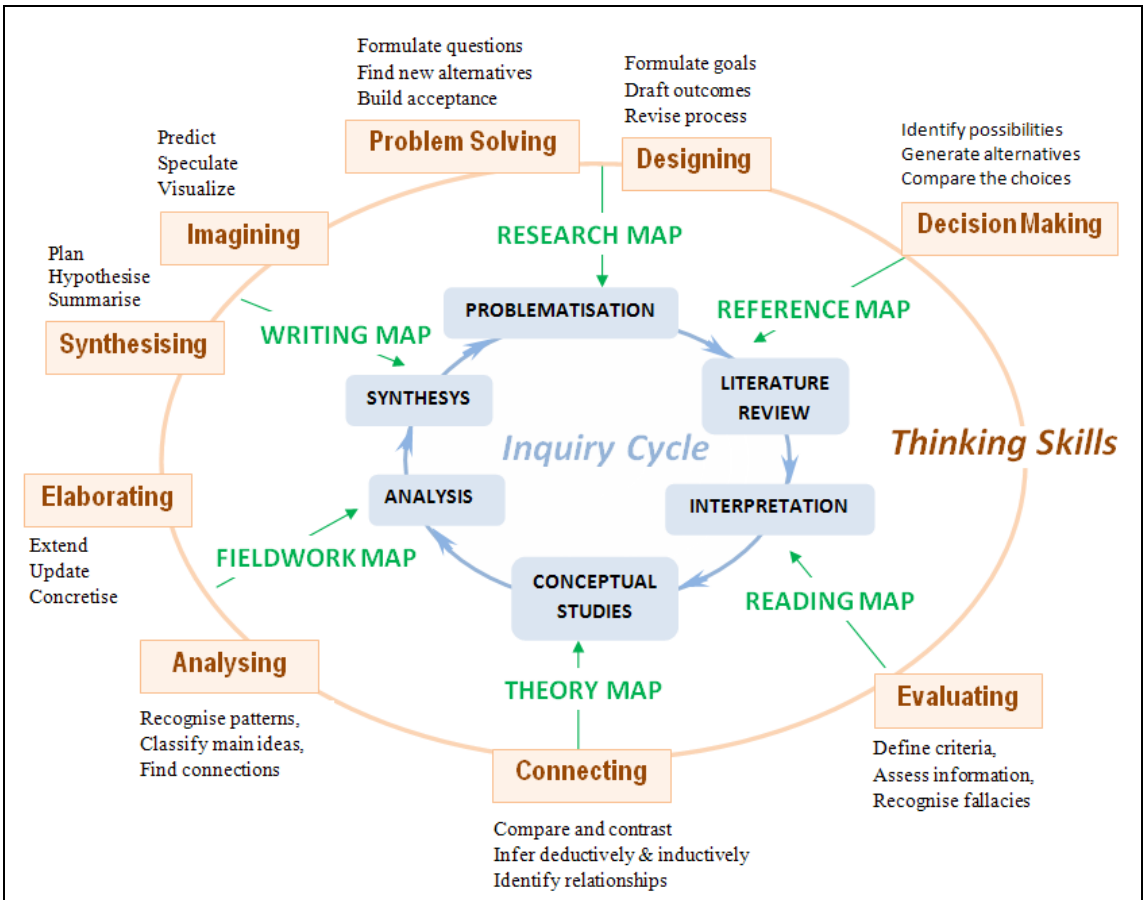
Making maps helps learners make their thinking explicit and that this can support them in the metacognitive process of developing better thinking strategies. The inquiry pathways represented by inquiry maps provide learners with graphical representations for reflecting in action and reflecting about their own reflections during their research projects. Inquiry maps can be applied in several stages of a research project to make thinking visible by drawing out lines of reasoning. These inquiry pathways provide researchers with representational guidance to interpret and construct meanings by visualising key components and their connections.

Paul (1992) emphasises the importance of thinking about thinking. Eliciting thinking skills require students to think in order to improve their own thinking by skillfully taking charge of the structures inherent in thinking. He defines critical thinking as the capacity to question positions, arguments, assumptions and values in order to identify the real meaning. Thinking skills comprise the ability to formulate, analyse and assess problems. It also implies the study of assumptions, concepts, evidence, inferences, purposes and consequences.

In order to investigate the use of inquiry maps in academic research for eliciting thinking skills, this qualitative research draws on the work of Jonassen (2000) who points out some principles to elicit thinking skills in terms of:

- Content/Basic Thinking: It represents the ability to make sense of accepted information, declarative and explicit knowledge. It refers to the skill of interpret general knowledge and common sense information. Content basic thinking requires learning and retrieving what has been learned.
- Critical Thinking: This represents the dynamic process of mapping knowledge in meaningful and usable ways though analysis, evaluation and connections. It integrates important skills such as evaluating the process by appropriate criteria analysing interrelationships among relevant elements mapped through connections and recognising gaps, vagueness and misunderstandings.
- Creative Thinking: It shows the ability to go beyond accepted knowledge to create and reconstruct new knowledge. Creative thinking must be connected to content thinking and critical thinking in order to integrate existing knowledge with the skill of innovative thinking.

Figure 1 describes six kinds of inquiry maps which can be used to develop six stages of a research project. It also presents the types of thinking skills which were integrated by the author in the inquiry cycle .



Inquiry Maps	Thinking skills	Research Steps
Research Map	Problem solving Designing	**Problematisation:** map a brainstorm of questions in order to find key issues
Reference Map	Decision-making	**Literature Review**: map relevant sources of reference in order to select key literature to ground your ideas.
Reading Map	Evaluating	**Interpretation:** map the content of the selected papers to make sense of key concepts
Theory Map	Connecting	**Conceptual Studies:** map different approaches to integrate a key body of knowledge
Fieldwork map	Analysing Elaborating	**Analysis:** map your data based on an appropriate inquiry method to address the research questions
Writing map	Synthesising Imagining	**Synthesis:** map key components of the research process: issues, references, concepts, methods, data and findings in order to visualise key arguments and develop a coherent summary.

Figure1: Eliciting thinking skills through inquiry maps Okada (2006)

3- Framework for assessment: Inquiry Maps in CLE

Baker (2003) emphasises that collaborative problem-solving and argumentative discussions help students choose better problem solutions, develop thinking skills and co-elaborate deeper understanding. McTighe (1992:190) points out that the uses of graphical representations in CLE benefits students in at least four ways:

1. *They provide a focal point for group discussions by offering a commons frame of reference for thinking*
2. *They provide a "group memory" or tangible product for the group's discussion*

3. *They encourage students to expand their own thinking by considering different points of view*
4. *They helps to articulate diverse lines of reasoning and helps to render the invisible process of thinking visible for all participants.*

However, some scholars argue that maps constructed by learners are difficult to be understood by other learners (Mayer, 2003). Representational notations in maps manifest themselves as constraints, presenting limits on expressiveness, and on the sequence in which knowledge units can be expressed (Suthers, 2003). A map's content can be clear for some mappers, but sometimes can not be understood for some readers. "Maps can work well as a tool for one's own sense-making, but not necessarily as a tool for transmitting knowledge to someone else (Zimmer)" (Okada and Connolly, 2008:12).

There are several factors involved for creating well-designed maps such as domain expertise, fluency with the tools, familiarity with mapping techniques (Okada & Zeiliger, 2003) and structural patterns (Chen and Czerwinski, 1997).

The "*elicit*" principles developed by Okada (2004) during the online course aims to provide some guidelines for applying mapping tools and techniques to create well designed maps. Through some structural patterns, maps can be assessed and improved by offering a clear structure, easy to be understood according to six properties:

- **(E)**xplicit goals: Representing clear goals to be achieved with the map is an initial step for the inquiry pathway. This start point can be a question or problem. Making research aims explicit in the map helps researchers understand what they can use it for and start their research projects.
- **(L)**earning activities or research actions: Connecting learning activities in the map based on the research goals helps students plan next steps in their inquiry projects and visualise tasks that were not solved. This set of research actions will guide learners to achieve their aims during their navigation and mapping.
- **(I)**nteresting information: Integrating relevant information in the map will be useful for making sense of new concepts. Organising and connecting interesting information help researchers identify what they already know and what they want to discover.
- **(C)**lear connections: Describing connections through links, text, and icons can be meaningful for making the lines of reasoning explicit. Structuring connections without making the map confusing adds more value by making the thinking process clear.
- **(I)**ntegrated overview: Getting the big picture in the map means be able to zoom out the map and visualise the connection among the most relevant points - familiar and unknown ones. Offering a big picture of the main topics through a simple map interface will allow researchers to see the key information initially and, through the pre-defined filtering or layering process, give them the opportunity to magnify or zoom into the areas that they want to explore.
- **(T)**rail as a marked route: Visualising and tracing learning pathways means to explore, discover, and ascertain significant steps. This trail with key steps will help learners to feel more confident in exploring, discovering, and ascertaining different pathways without becoming lost.

Another way to improve maps is the ability of assessing maps in group. Learners can improve their maps by getting collaborative feedback about what is not clear (Veerman, 2003).

Research students must be aware of questions such as: What is this map for? What am I trying to accomplish by using this map? What does this map show that I want to discover? What does this map show that I already know? What is missing in this map that I should include to make it clear? Is there anything that I could change in this map to make it more useful? What other situations and issues that this map can be useful for?

Table 2 shows some questions that teachers and researchers used in this course to assess collaboratively each kind of inquiry maps.

Inquiry Maps	Rubrics	Some questions to assess content of maps
Research map	**Research-questions**	• Does your map present good research questions or aims?
	Research-description	• Is your research project well described through key questions: What? Why? For what? Who? Where? How? When?
	Research-knowledge	• Is your prior knowledge about the topic visible?
Reference Map	**Reference-relevance**	• Does your map indicate relevant references in the field?
	Reference-quantity	• Does your map show enough references to start your study?
	Reference -structure	• Are your references well organised by key concepts?
Reading Map	**Reading-summary**	• Does you map show a good summary of your text
	Reading-headings	• Are the key concepts to structure your reading well described? (theme, relevance, aims, concepts, analysis, claims, evidence, conclusion)
	Reading-understanding	• Does your map allow you to understand the content?
Theory Map	**Theory-relevance**	• Does your map present relevant theory?
	Theory-viewpoints	• Does your map integrate different viewpoints?
	Theory-meaning	• Does your map allow you visualize new meanings?
Fieldwork Map	**Data-relevance**	• Does your map present relevant data from your fieldwork?
	Data-quantity	• Does your map show enough data for your study?
	Data-structure	• Is your map well structure allow you find specific data quickly?
Writing Map	**Writing-structure**	• Does you map present a clear structure for you writing about your research?
	Writing-connections	• Does you map connect key-categories such as context, hypothesis, aims, background, methodology, findings, and considerations?
	Writing-understanding	• Does your map help you write your understanding about the topic?

Table 2– Table for Assessing Inquiry Maps (Okada, 2006)

Another relevant step to improve knowledge mapping is evaluating aesthetic characteristics of a map. The content of an inquiry map can be better understood when researchers improve their maps' structure. Well structured maps can facilitate the process of inquiry as well. *Table 3* presents the questions that teachers and researchers used in this course to help them evaluate structure, illustration and layout of their maps.

Rubrics	Some questions to assess aesthetic characteristics of maps
Structure	Is the title of the map visible and clear? Are the components and their connections well organized? Are the relationships between objects well described? Is the map easy to be understood?
Illustration	Does the map offer a global picture of its content? Are the components relevant and clear? Does the map achieve its purpose? Does the map allow you to understand its content?
Layout	Is the design of the map clear? Are the text and images well organized in the map? Are the connections visible and easy to be identified? Does the map allow you to read and browse its content easily?

Table 3– Table for Evaluating Inquiry Maps (Okada, 2006)

4. Case Study - Fostering Critical Thinking through Inquiry Maps in CLE

In this section, some strategies about the uses of conceptual maps to foster critical thinking in CLEs are presented. In order to understand how this framework can be applied in online courses, I analyse some maps built by a community of researchers during the online course "*The uses software in qualitative research*" (USQR).

4.1 CLE – Our Aims

"*The uses of software in qualitative research*" (USQR) was an online course organized by the author at Pontificia Universidade Catolica in Sao Paulo Brasil between 2004 e 2005. The aim of this course was to apply mapping techniques in research projects.

In 2006, the author organized another course entitled "*Writing academic papers using maps*" (WAP) for all previous participants interested in some mapping techniques to write academic papers. In 2007, the author published the online course at OpenLearn Project for the Open Research Community in Collaborative Learning CoLearn to map open educational resources.

The learning outcomes of this online course were to:

- ✓ Understand concepts which underpin the uses of mapping for qualitative research.
- ✓ Apply mapping techniques in a research project to collect web resources (web mapping), generate new ideas (mind mapping), organise concepts (concept mapping) and structure arguments (argument mapping).
- ✓ Use different mapping software tools, depends on the context and interests, such as: Nestor Web Catographer, CMap Tools, FreeMind and Compendium.

The learning outcomes of the WAP course were to:

- ✓ Analyse key ideas during academic papers reading
- ✓ Integrate most relevant ideas from different sources
- ✓ Systematise key arguments for writing academic papers

4.2 CLE – Academic Actors and their Networks

The participants of this community were postgraduate students, researchers and lecturers. *Table 4* shows participants who registered in the courses, completed all activities and at the end participated in the Emapbook. Some participants, due to had personal problems, had to leave the community before finishing the course. For instance, in USQR2 40% of the participants were busy finishing their thesis; therefore the participation was lower than other groups. Few students had problems with equipment, internet and software tool installation and were not able to participate.

Participants	**2004** USQR**1**	**2004** USQR**2**	**2005** USQR**3**	**2005** USQR**4**	**Total**	**2006 WAP**
Registered	15	13	9	18	55	12
Active members	14	7	6	15	42	12
Emapbook authors	9	6	5	10	30	24

Table4 – Participants of online courses about the uses of maps for research 2004-2006

Table 5 shows the participants of this research community organized by fields and professional activities, while *Table 6* shows the participants organized by their cities. Most participants were PhD and MA students (20) from São Paulo (25).

Participants	Qt	Field
Lecturers	7	Biology, History, English Language and Computer Science.
Scholars	5	Medicine, Psychology, Business, Marketing, Law.
Educators	7	Education, History, Social Science, Health.
MA students	11	Education, Business, Maths, Journalism, Social Science, Biology,
PhD students	8	Education, Economy, Social Science, Technology, Anthropology.
Research fellows	4	Economy, Architecture, Maths, Psychology,

Table 5 – Participants - Field

Location	(Brazil)					(UK)	(Portugal)
	Sao Paulo	Rio de Janeiro	Bahia	Goias	Rio G. do Sul		
Quantity	25	5	3	3	2	2	2

Table 6 – Participants - Location

In the CLE environment, the participants introduced themselves through concept maps using CMap tools to describe their personal and professional life. *Figure 2* shows the example of a MBA student´s concept map created to introduce herself in the USQR community. The text shows some information about Laura´s professional and personal life. The content in the map is different to the text. It shows how she represents her reflection about herself. In this map, Laura points out three dichotomies in her life. She indicates some of her skills (e.g. ability to connect ideas and concepts quickly) and difficulties (e.g. low ability to be focused). In this example, it is possible to notice that introducing herself through concept map helped her reflect on and share her personal aspects as a researcher. The map reveals some aspects of her personality that are not described in the text.

When participants created and shared maps in the CLE, they started to know each other and themselves in different ways, which promoted more thinking and familiarity with the group. The research students mentioned that maps were useful to identify common interests and similarities between them, which helped their communication, and collaboration.

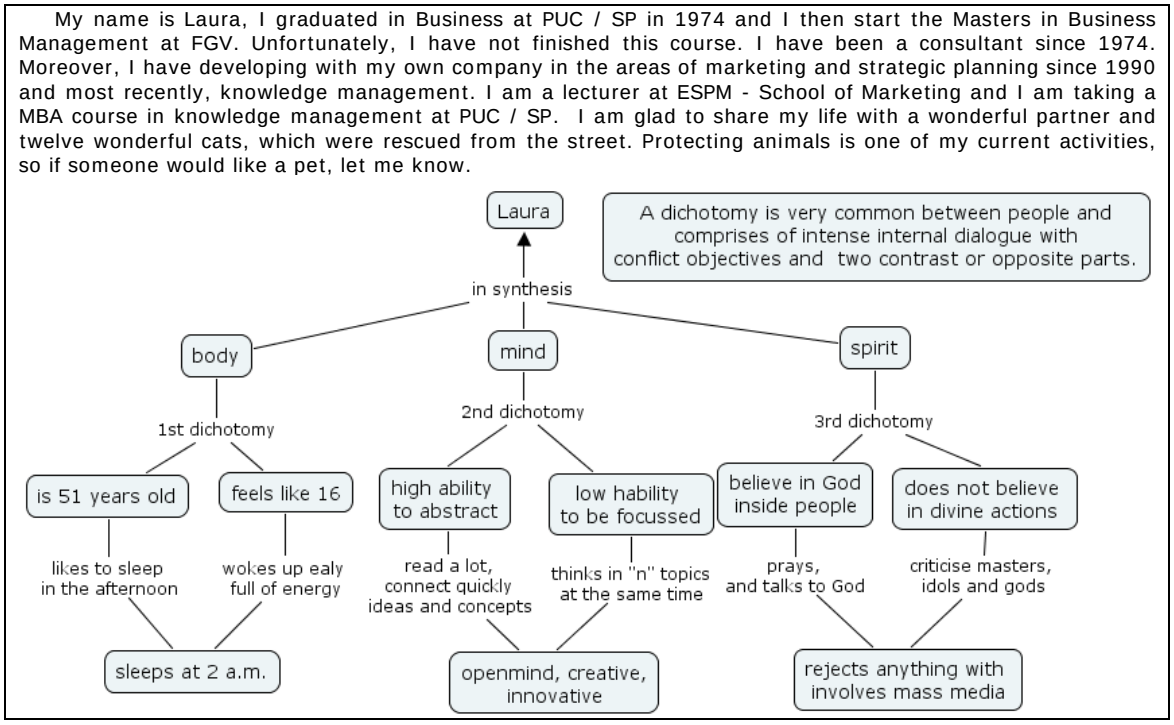


Figure 2 – Personal map for participants´ introduction to USQR with Cmap Tools.

4.3 CLE – Interactions and learning activities

Learning activities were planned to make the participants explore collectively mapping techniques in their individual research projects and also to reflect and discuss about the uses of mapping techniques to develop academic projects.

The course was organized in two parts: (1) Mapping techniques and software tools.

(2) Mapping techniques and qualitative research.

In the first part, the participants introduced themselves in the forum; they installed the software tools and explore different kinds of mapping technique such as concept maps, mind maps and webmaps. The second part, whose content was presented through a learning path map (*Figure 3*), focused on principles to support the uses of maps in qualitative research. Its first activity was a "round table", where four authors Moraes, Macedo, Canas and Zeiliger presented papers with discussion forums with questions related to authors' papers. In the second activity, the participants had to improve their research map based on teacher´s feedback and colleagues´ comments. In the third activity, they should work in groups in order to evaluate and improve their maps. Finally, they should write a paper with their maps (map-paper).

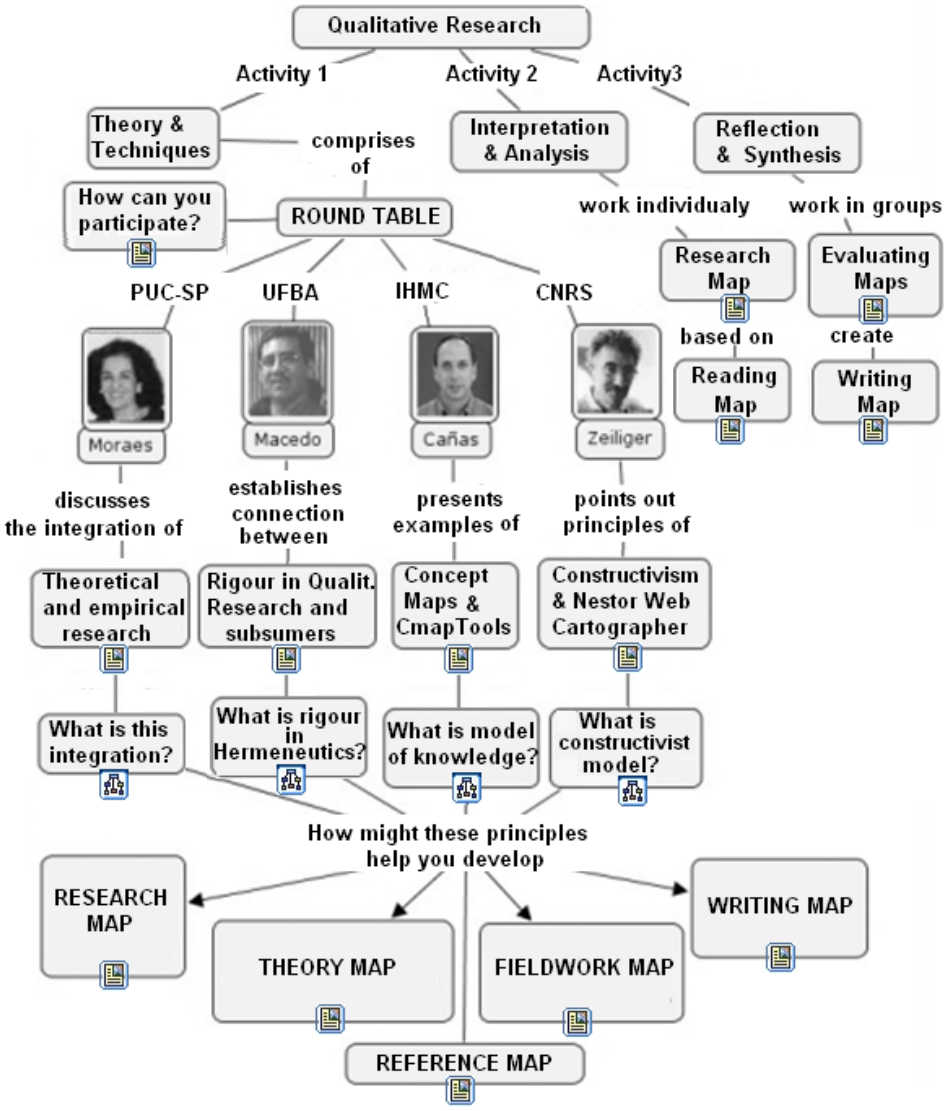


Figure 3: Learning path map created in Cmap tools created by Okada (2004).

Through a learning path map, the participants were able to visualise a global picture of learning activities and identify groups to interact and give contributions. They were able to navigate through hyperlinks, select papers to read and choose groups to discuss based on their interests.

The participants exchanged ideas in the discussion forum about the papers, raised new questions and shared their reflections about new concepts (e.g. subsumer, theoretical and empirical research, models of knowledge and constructivism approach). Some participants logged the following in their blogs:

- *"The website of an online course is more attractive and objective through concept maps"*
- *"Maps allow us to visualize different options and select what we are interested in"*
- *"Maps help us identify relations between concepts while we are browsing the content"*
- *"Through maps, it is easier to connect our reading to activities and learning goals"*

4.4 CLE – Individual and collective contributions of participants and groups

The online learning environment was created to promote a virtual community of research. The learning activities were planned to engage participants in collaborative learning. The technology used was a Moodle platform, in which several maps were integrated to present the participants' life history, online content and collaborative tasks.

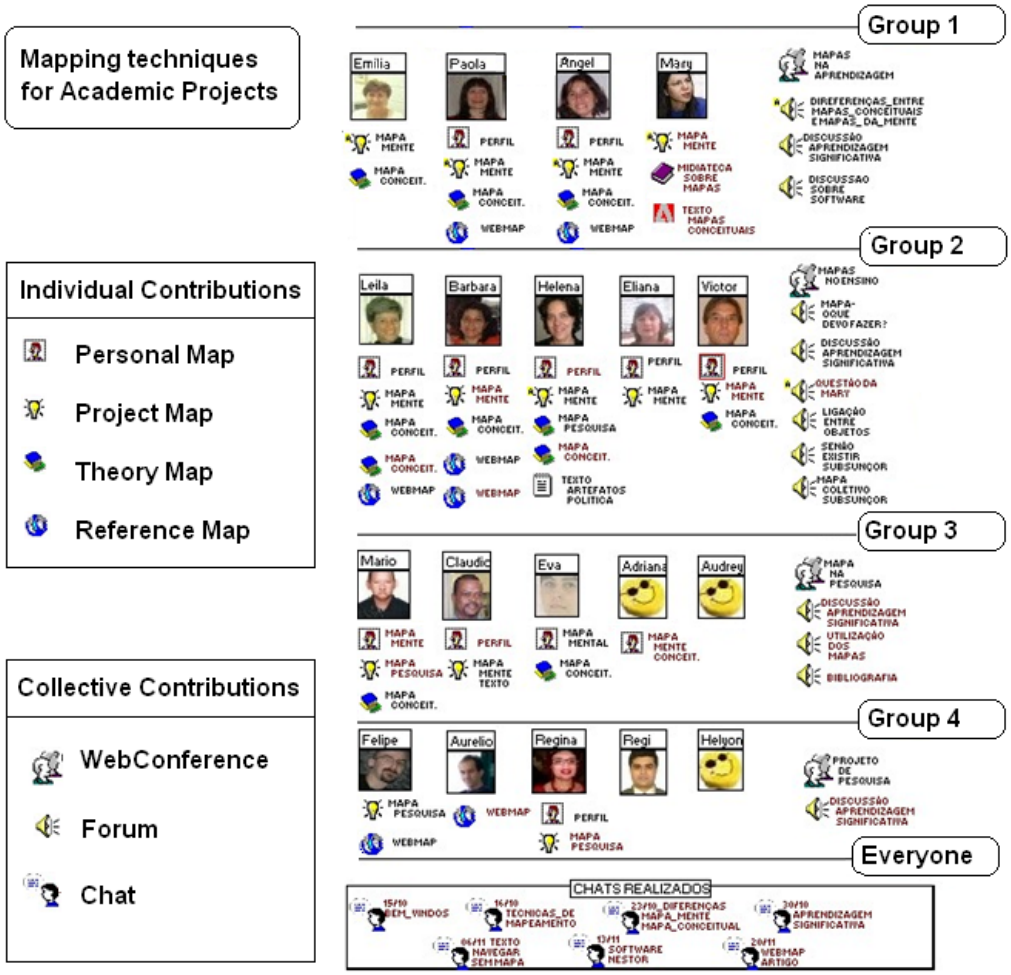


Figure 4: Portfolio map about individual and collective productions in Nestor Web Cartographer created by Okada (2005).

Figure 4 shows a portfolio map, where the participants accessed interfaces to share their ideas, work samples, maps and papers. Through this map, they were able to visualize, navigate and choose different interfaces to add individual or collective contributions:

- Forum – asynchronous interface for exchanging ideas, where participants confronted questions and discussed meanings in order to make sense of theory and methodology.
- Chat – synchronous interface for exchanging ideas, where participants described their problems and contributed with solutions about technology.
- Videoconference (FM tool) – synchronous interface for online meetings, where participants discussed their productions and feedback.
- Wiki –collection of web pages for constructing text collaboratively.
- Blog – website with regular entries of commentary, where participants shared on self-reflection about the research and learning process with feedback of all participants.
- Maps – graphical representations created in different tools.

Participants described that the portfolio map allowed them to:

- *"feel engaged to share more content by visualizing all contributions"*
- *"follow own progress and identify easily where to add or update content"*
- *"access other colleagues´ contribution quickly to give them feedback"*

4.5 CLE – Collaborative productions: e-mapbook

The e-mapbook (*Figure 5*) is an electronic book in Portuguese, which was produced collaboratively by thirty participants (described in Table 4) of the USQR community and organized by the author.

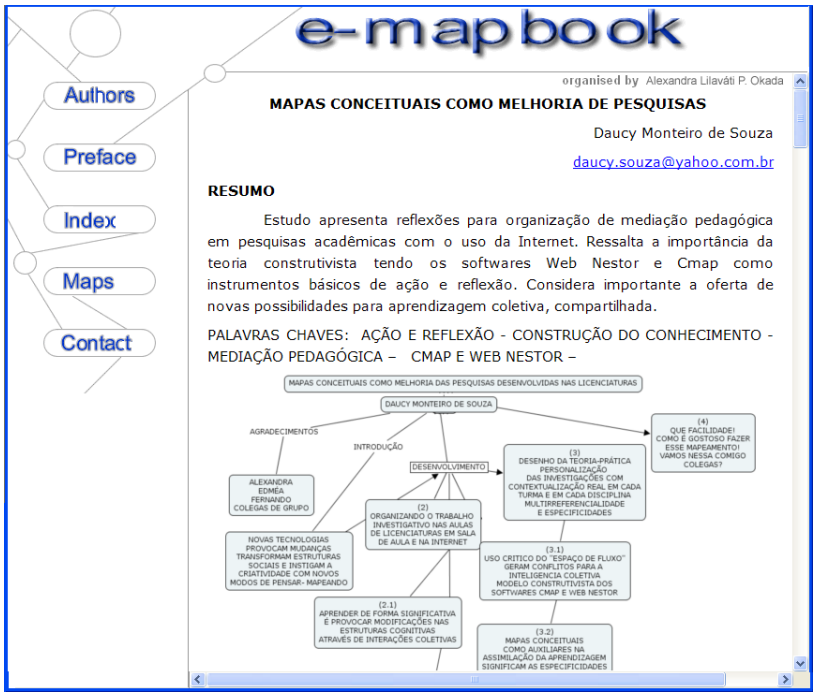


Figure5: e-mapbook published in Portuguese http://projeto.org.br/emapbook/

Figure 5 shows also a map paper about "*Concept maps to improve research*" by Souza with research map, theory map and reference map. Souza commented that publishing a paper and participating in the review process helped her develop critical view of her work.

4.6 CLE – Individual productions: Inquiry maps for developing academic research

In order to present the benefits of using inquiry maps for developing thinking skills in research projects, we selected thinking skills, which were described in Figure 1, to analyse six models of maps: research map, reference map, reading map, theory map, fieldwork map and writing map. *Table 7* shows these principles and the messages written by the participants in their blogs. These messages describe how researchers analysed the contributions of mapping for developing their project and their thinking skills.

Inquiry Map	Thinking skills	Researchers' comments
Research Map	**Problem solving**: reformulate questions, find new alternatives, build acceptance **Designing**: formulate goals, draft outcomes, revise process.	*"Through my research project I could find a focus for my research. After creating several maps of my investigation, I could visualise the main ideas and identify the key questions of my research."*
Reference Map	**Decision-making:** identify possibilities, generate alternatives, compare options.	*"Constructing a map to select references make me think what are the most relevant literature to support my research and how could I group them to facilitate future studies"*
Reading Map	**Evaluating:** define criteria, assess information, recognise fallacies	*"Structuring my reading through maps are very useful for extracting key ideas from texts."(…) " It makes me reflect more about what the meaning of each sentence an how to categorise relevant information"*
Theory Map	**Connecting:** compare and contrast, infer deductively and inductively, identify relationships	*"Using maps to connect different perspective from the same concept is very challenging. Maps can reduce the meaning of concepts and it is hard to summarise in few words complex definitions." (…) "However, they help us to compare different approaches and identify connections to reconstruct new meanings"*
Fieldwork map	**Analysing**: recognise patterns, classify main ideas, find connections **Elaborating**: reflect, widen and deepthen, update, concretise.	*"The main contributions of organizing a field work through maps, (when you have electronic data - text, image and audio), are - navigate easily in the corpus research,* *- classify and interpret data* *- making connections,* *- find and group relevant analysis based on different perspectives"* *"Although it is not easy to map lots of data, once you have your corpus well organised it is easier to recognise patterns and identify new issues to be clarified"*
Writing map	**Synthesising:** plan, hypothesise, summarise. **Imagining:** predict, speculate, visualize.	*"Maps applied to writing seems to be a great strategy because it help us visualize and integrate enough evidence to back up our claims, identify ideas to be deepened, approaches to be widened and plan a clear structure for presenting our thinking."*

Table 7 – Fostering thinking skills through inquiry maps in research projects

4.6.1 RESEARCH MAP – Introducing the research project through maps

The research map in *Figure 6* shows the structure of a research project with the main key concepts to generate a brainstorm: research questions or aims (what?), relevance of research (why?), contributions in the field (for what?), methodology of investigation (how?), work field (where?) and research schedule (when?). By using this structure, the participant was able to bring forty-one key ideas that might be useful to plan the investigation.

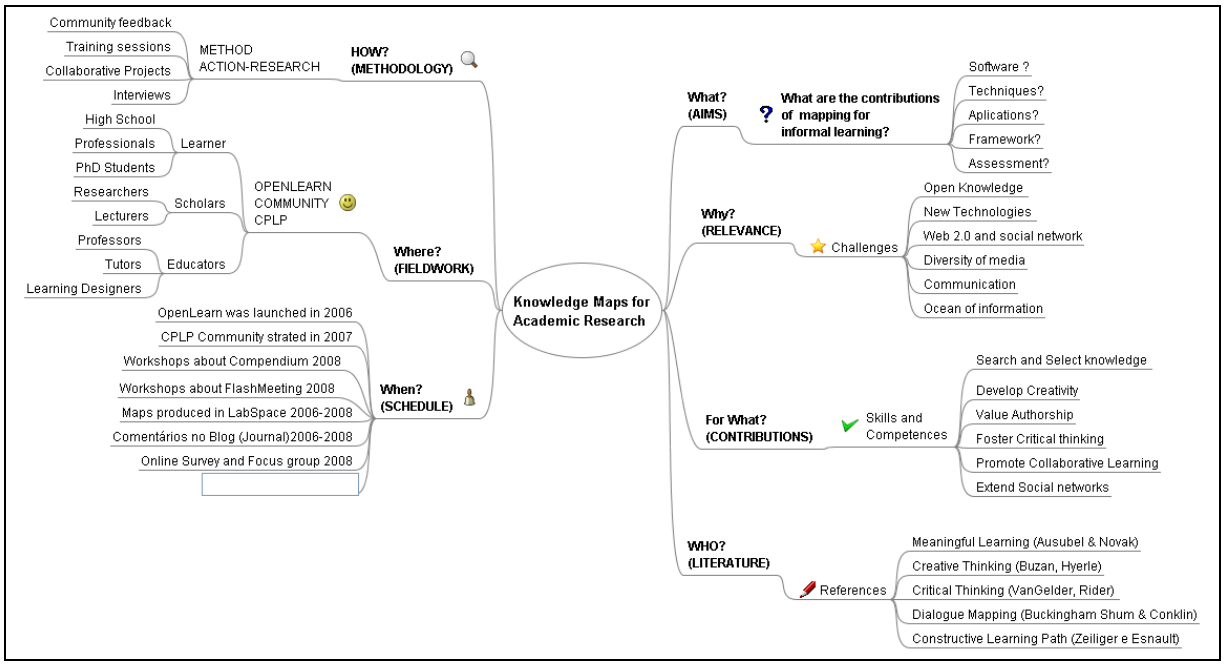


Figure 6: Research Map created in a FreeMind

Good inquiry projects depend on significant questions. At the beginning of a research, it is not easy to define a relevant issue. Initially, students and researchers can be lost when they have to face lots of information without questions, or when there are many questions but no significant references. Mapping the starting point of a research project can help people to find better questions (Conklin, 2006).

Learners can connect prior knowledge and initial questions in order to find an important issue to be investigated through a "research map". Mind mapping can be used to generate a brainstorm of key research issues and to organise the initial structure of a project. Finding a significant and innovative issue becomes easier when relevant information is mapped.

The research students described that mapping their project helped them find out critical topics that need to be explored better. The identification of new possibilities and difficulties facilitated a continuous process of elaborating new questions in order to the delimitating better the focus of their research.

4.6.2 REFERENCE MAP - organising references

The reference map in *Figure 7* shows 82 documents related to critical thinking literature review classified by nine conceptual categories (glossary, papers, website, case study, foundation, abstract, software, thesis and books) and 16 types of icons. The icons can be useful to distinguish different kinds of content, or format.

During the construction of reference maps, researchers identified some benefits. Mapping papers on the web, intranet, or own computer helps to locate easily a set of documents about a specific topic. Representing many documents in a small space offers a global overview of the literature selected. Maps are also useful to answer the following key questions:

- What are the main articles, papers and other references?
- What are the key theories, foundations, concepts and origins?
- What are the main case studies?
- Is there any technique or tool involved in this process?
- What are the major debates about the topic?

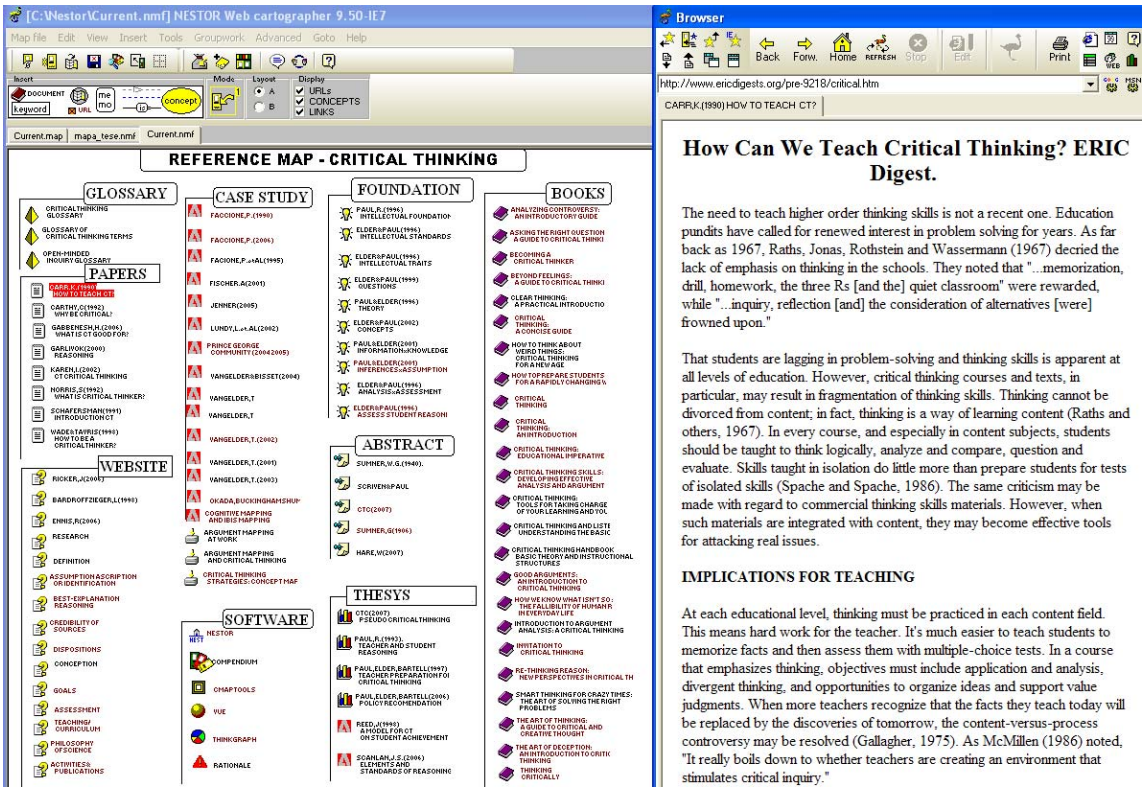


Figure 7: Reference map about critical thinking created in Nestor Web Cartographer

Web mapping for organising references help users get an overview of relevant information from different areas of knowledge, languages, formats and media through web maps (Okada and Zeiliger, 2003).

The participants pointed out that reference maps created through web mapping were useful for selecting, organising and updating diverse references in their investigation. The graphical representation facilitates the process of storing, retrieving and sharing different kinds of documents. It was easy to add summaries, classify materials using categories, and establish connections between them. Visualising all references through maps allowed participants to compare contents and reuse them in other research projects.

4.6.3 READING MAP– Interpretating and analysing papers

This reading map in *Figure 8* about a PhD dissertation presents initially 24 keywords related to critical thinking and the number of frequency which they appear in the text on the top of the map. Its structure is organised by 15 categories: from theme to results. A reading map helps researchers not only summarise the document, but also review, remember and reassess the content. Different categories can be chosen to analyse different kinds of documents. Identifying a significant structure helps readers to browse and study the paper. Through a set of categories, they can organise the main topics of the paper, locate easily the mains ideas and construct a memory system. Moreover, a reading map might help readers explore and make sense of big documents.

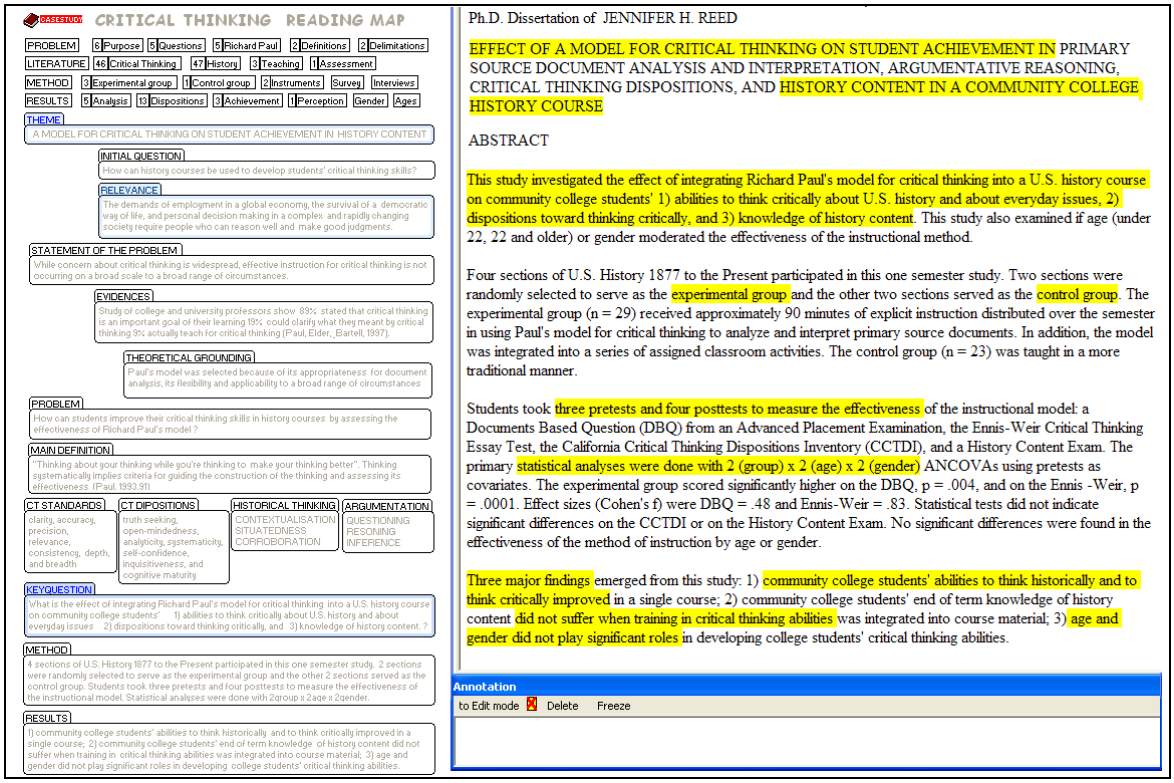


Figure 8: Reading map about PhD dissertation about critical thinking created in Nestor

Selecting significant references entails interpreting the content. Interpretation implies analysis in order to apprehend meanings (Ricoeur, 1974). It means breaking down the complex text into simple parts. Mapping important statements of a document and their interrelationships helps readers to interpret new concepts. Through reading maps, they can visualise what is important, store and retrieve pieces of information quickly.

A deep analysis of papers allows researchers to identify a network of concepts and lines of reasoning. These abstract elements when are represented in maps turned into concrete elements able to be recombined.

The participants found reading maps useful for understanding how conclusions were drawn from a set of evidences, arguments and contra-arguments. They were able to highlight important key concepts and ideas and use the same template for other papers and also research projects. Mapping the reading process helped also researchers identify new references from the bibliography, which were included in their reference map.

4.6.4 THEORY MAP – Understanding concepts

This theory map (*Figure 9*) shows three perspectives (context, key definitions and key concepts) to organise different meanings for "critical thinking". For that, 14 definitions from different authors were selected, grouped by context and ordered by date. From these definitions, 16 words were generated to capture the key ideas, which were integrated in a conceptual area. Researchers consider theory maps as a guide to help them interpret different viewpoints, compare and combine different approaches to reconstruct their own interpretations.

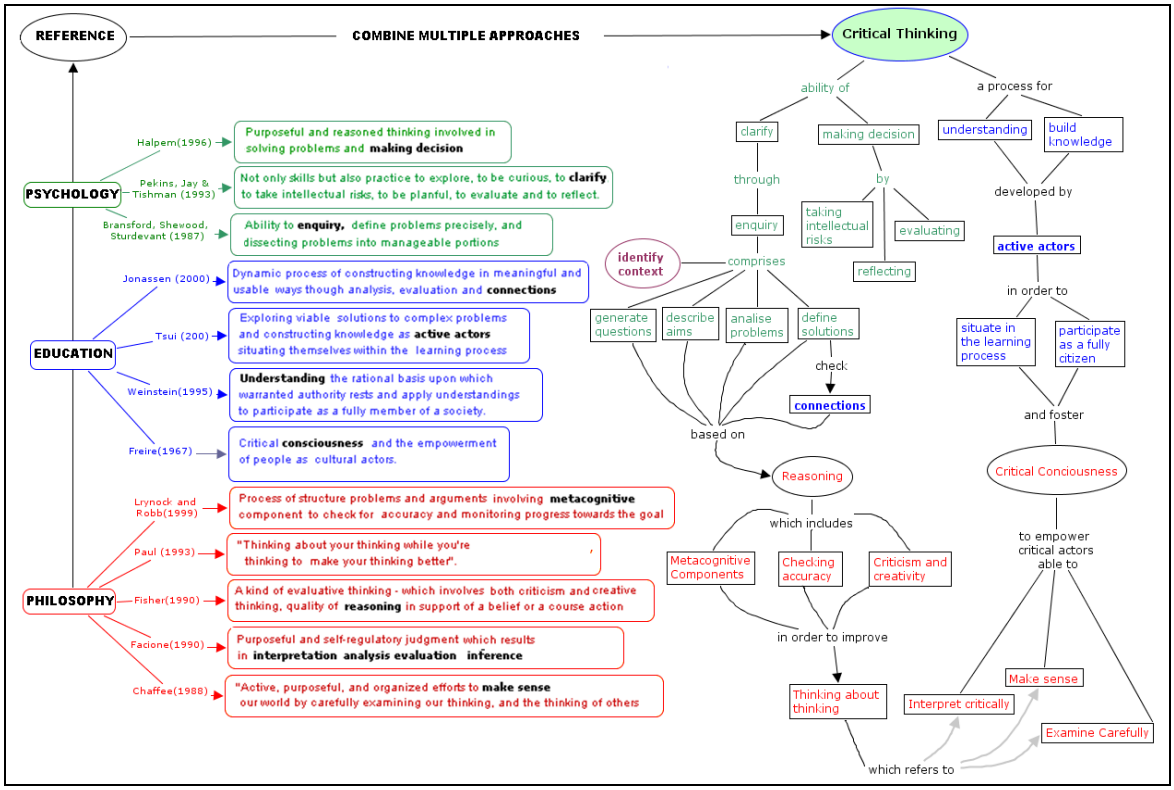


Figure 9: Theoretical map about critical thinking created in CMap tools

Clarifying concepts is an important step to understanding theories and for meaningful learning (Novak, 1998). Mapping several sources from different authors that explain the same concept helps researchers select and reconstruct maps from a wide and more significant perspective. When concepts are well mapped, learners can compare, combine and reintegrate similar groups of references.

The participants' discussions indicated that theory maps helped them visualise gaps and misunderstanding for further investigations. They identified new concepts that should be clarified. Theory maps were useful to connect concepts, definitions and the original source by organising a graphical memory system of their studies. Participants described that they were able to represent and reconstruct semantic networks from their own perspective and reuse theory maps in different inquiry projects.

4.6.5 FIELDWORK MAP – Collecting and analysing data about the fieldwork

The fieldwork map in *Figure 10* describes a case study about the online course USQR. This graphical representation created in the mapping tool Compendium shows the 30 participants and all their mapping productions and research diaries classified by time, topics and grouped by portfolios.

One of the main benefits of fieldwork maps is to classify and connect the most important data and navigate in different contexts. Visualising and analysing key data through maps is also useful for reorganising multiple views and get an overview of the most relevant findings.

Figure 10: Fieldwork map of a PhD research created in Compendium

Analysing lots of data during an empirical study demands deep and systematic reflection Whyte(1991). Well-designed maps can facilitate the process of analysis mainly when important components are well connected. Thus, researchers must be aware of important issues that might help them create their fieldwork map, such as:

- Criteria from the methodology which assure rigour and quality of analysis;
- Instruments to collect data, organised by categories.
- Theoretical categories from theoretical maps to guide the empirical analysis
- Reflective annotations to interpret their empirical investigation

When these issues are integrated into fieldwork maps, researchers are able to reinterpret their meaning visualising parts and the whole context. They are also able to reconstruct several maps to see different perspectives. New key concepts from the field study can emerge generating new categories resulting in a reconstruction of better maps.

Some of the research students wrote that through fieldwork maps, they were able to categorise the main key concepts, include comments about the analysis and integrate relevant data in different perspectives. They also described that when lots of maps are constructed, one critical issue is to focus on the main research question. The fieldwork map can then be used as a guiding tool, by reminding the key issues and main direction to follow.

4.6.6 WRITING MAP –systematising the research.

After mapping theories and the fieldwork, the next step is to map the research's outcomes and synthesise a significant conclusion. It means integrating each relevant component to form a coherent whole. For that, a well-structured map is useful to organise ideas clearly and coherently. Mapping for arguing (Andriessen, Baker & Suthers, 2003) can help researchers and learners describe and visualise their line of reasoning. Visualising argumentation (Kirschner, Buckingham Shum & Carr, 2003) in a map facilitates the process of assessing claims by checking if there is enough evidence and facts that support key ideas. Therefore, drawing a coherent conclusion is easier when claims, arguments, counter-arguments, evidence and facts are well connected in a writing map. Writing maps are useful not only for facilitating the process of writing but also for understanding how the research problem was answered.

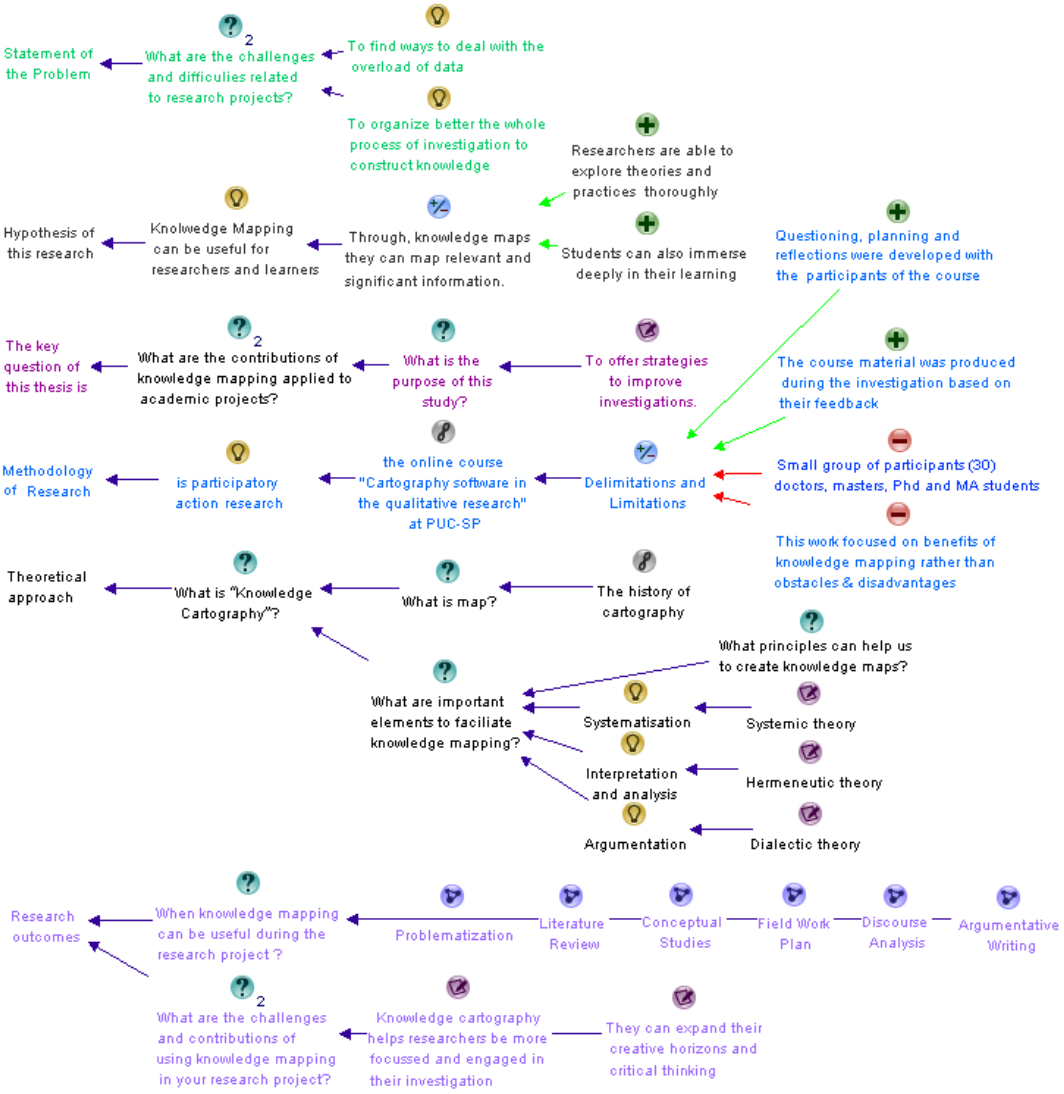


Figure 11: Writing Map of a PhD research created in Compendium

The writing map in *Figure 11* shows a rational structure to facilitate scientific writing of a PhD research abstract (see *Figure 13*) . It presents 47 statements: titles, questions, answers, notes, pro and cons. The participants described that a writing map was useful for organising lines of reasoning in a logic and objective way. The writing map helped them organise an argumentative structure and communicate clearly the relevant aspects of their research.

Figure 12:. Outline view of a Writing Map of a PhD research created in Compendium

ABSTRACT - "One of today's great challenges in the context of' research and learning is to find ways to deal with the overload of data. New techniques are needed to organize better the whole process of investigation to construct knowledge. When relevant and significant information is mapped, researchers are able to explore theories and practices thoroughly. Students can also immerse deeply in their learning. The key question of this thesis is "What are the contributions of knowledge mapping applied to academic projects?" The intention of this work is to offer to researchers strategies to improve their investigations.

To answer this problem, I based my investigations on the course "Cartography software in the qualitative research" at PUC-Cogeae Online, from 2003 to 2006. The methodology of this research is participatory action research. Questioning, planning and reflections were developed with the research students and the course material was produced during this investigation. About limitations of this research, the experiment group was small, 30 participants: doctors, masters, PhD and M.A. students. This work focused on benefits of knowledge mapping rather than obstacles and disadvantages.

In this work, I define what "Knowledge Cartography" is starting with the history of cartography and the concepts of maps and investigation. After that, I discuss epistemological principles to guide the creation of inquiry maps, with reference to systemic, hermeneutic and dialectic theories. Then, I analyse the practice, discussing the contributions of mapping in various stages of research: problematisation, literature review, conceptual studies, fieldwork plan, discourse analyses and argumentative writing. In the end, I emphasize how knowledge cartography helps researchers be more focused and engaged in their investigation, and at the same time they can expand their creative horizons and critical thinking."

Figure 13. Abstract of a PhD research developed from the writing map

5. Discussion

The first purpose of this study was to identify the contributions of applying inquiry maps to academic projects.

Inquiry maps and comments written by participants indicate that they were able to:

- select and organise relevant content,
- structure and represent their thinking graphically
- integrate new concepts and their own interpretation .

The participants pointed out that research map used to represent key ideas enabled them to find their key questions. The reference map helped them organise the literature review. The reading map was useful to interpret papers. The theory map facilitated the integration of different viewpoints about the same concept. The fieldwork map provided interesting ways to analyse data. Finally, the writing map was a good strategy for summarising key ideas with arguments and evidence. Through these inquiry maps and their discussion in the CLE, teachers could also observe that participants were very engaged in applying these mapping techniques to develop their researches.

This study indicates different uses of inquiry maps to develop thinking skills in academic research. Inquiry maps created by researchers show that graphical representations may be useful for developing *the inquiry cycle* (Llewellyn, 2005) and *the spiral of research* (Blaxter, Hughes and Tight, 2001). These two approaches used to develop a scientific investigation describe six steps that in this study were summarised as: *Problematisation, Literature Review, Interpretation, Conceptual Studies, Analysis and Synthesis* illustrated in Figure 15. These six kinds of inquiry maps applied to academic research may help researchers to implement and integrate these six steps better.

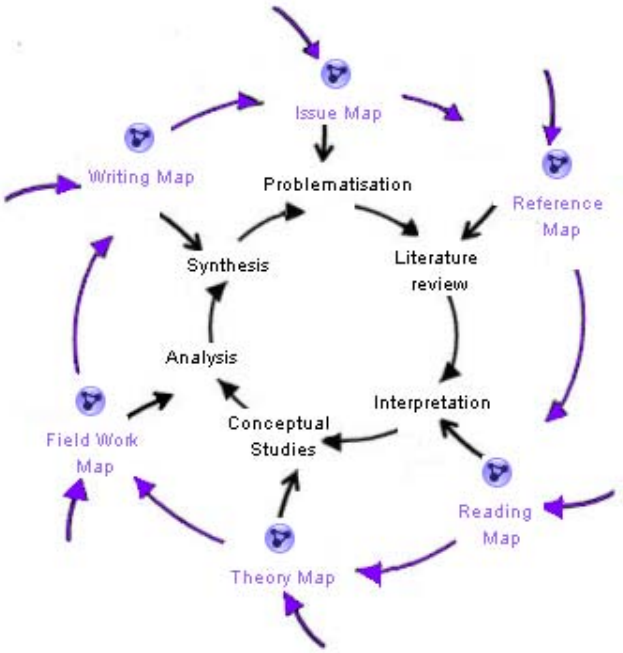


Figure 15 Research flow map created in Compendium

Most of the participants (80%) in this course were able to create research maps, references maps and theory maps. Few participants (10%) who had already collected electronic data from their fieldwork were able to create fieldwork maps. In addition, some researchers (30%) who were interested in improving their writing skills elaborated reading and writing maps. In this study, the participants did not apply these six kinds of maps to develop all steps in their

research, because most of them were busy in different stages in their investigations and they also presented different priorities. However, the integration of these inquiry maps to develop a research project will be theme for our next investigation in the CoLearn Community.

The second purpose of this study was to identify the benefits of using CLEs with diverse mapping techniques for participants. The collected data indicate that the CLE helped students learn and apply mapping techniques and software tools in their academic research. Inquiry maps presented in the CLE such as learning path maps and portfolio maps played an important role by engaging students in exploring contents, discussions and their productions. Research students were able to visualise connections between references, activities and learning goals through learning path maps, which helped them browse content and establish connections between theory and practice. Participants were able to access all contributions, discuss about their progress and identify where they could share constructive feedback through portfolio maps in order to improve their productions.

Knowledge integration environments (Bell, Davis and Linn, 1995) through inquiry maps seem to engage learners in developing and applying their thinking skills. Inquiry maps can guide them to find different spaces and groups to negotiate meanings, issues, claims and arguments with evidence and references. When CLEs stimulate learners to interact, contribute and develop productions together, they feel able to share cognitions and construct more knowledge that is significant together.

Inquiry maps can play an important role in CLE in representing collective construction of knowledge where all participants can access and connect different spaces such as questioning space, argumentative space and referential space (e.g. Figure 4) without feeling lost. Participants can negotiate meanings and add contributions connecting evidence. In this sense, these inquiry maps can help them develop and apply their thinking skills by analyzing and establishing more connections between referential space, argumentative space and questioning space in their maps and writing.

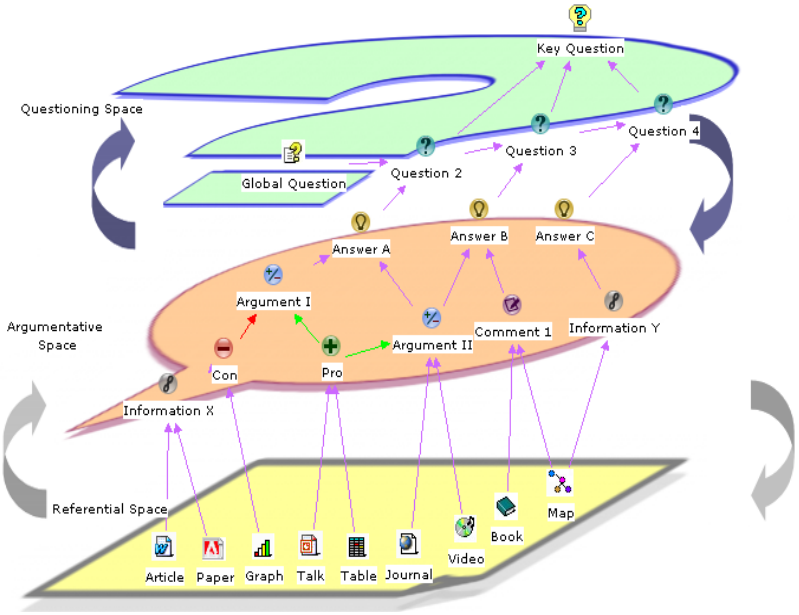


Figure 14. Research flow map created in Compendium

Concerning difficulties with inquiry maps in CLE, this study shows that learners (10%) who faced problems with their computers, internet or software tools, gave up learning.

The participants (14%) who mentioned be very busy in their professional activities did not find time to interact in groups and were not able to learn and apply inquiry maps in their academic projects.

Few participants (10%) who were not familiar with graphical representations with hyperlinks found it difficult to understand the content through maps. However when they started to produce their own maps they mentioned that learning path and portfolio maps were very useful.

Regarding the challenges of using inquiry maps to elicit thinking skills, several participants (60%) described that it was hard to explore diverse methods and different technologies.

However, after getting used to mapping techniques and tools, participants could identify differences and apply different resources better. In order to develop good maps it is necessary to get used to think graphically and create several maps. Participants also described that it is hard to avoid reducing the meaning of concepts in maps and to deal with lots of data. Some of them mentioned that big maps could be confusing and maps with several levels can be difficult to navigate and get the whole picture.

6. Conclusion and future trends

Findings drawn in this study describe the use of inquiry maps in academic research for eliciting thinking skills. The outcomes of this study also highlight the importance of collaborative learning environments to support researchers in exploring tools and applying mapping techniques in their academic projects.
This work presented six kinds of inquiry maps that can help researchers implement their scientific investigation and develop thinking skills:

1. Research Map
2. Reference Map
3. Theory Map
4. Reading Map
5. Fieldwork map
6. Writing Map

This work also described three kinds of inquiry maps that may help designers to plan collaborative learning environments:

1. Personal Map
2. Learning Path Map
3. Portfolio Map

Moreover, this study has identified some difficulties of the participants in using different tools, represent thinking graphically and creating maps with lots of data. Some insights, which have emerged from this work, such as the use of inquiry maps to develop academic research and the cycle of scientific inquiry will be the focus of the next studies.

The emergence of social software and Web 2.0 which creates new scenarios for open learning and collaborative construction of knowledge also highlights the importance of the ongoing research in this field. Inquiry maps may be considered strategic and heuristic tools for representing what is important, interpreting and reconstructing meanings, recording and sharing new structures of components and connections. All this skills are essential to foster critical thinking and make better decisions in research learning communities and social networks.

Acknowledgements

I am thankful to Dan Suthers and Tony Sherborne for their comments on an earlier version of this chapter and to peer reviewers of this book whose comments have contributed to the improvement of this final version. I am also grateful to Simon Buckingham Shum and Fernando Jose de Almeida for their comments and discussions in support of my work. Finally, thanks to the Brazilian Education Ministry Agency (the CAPES Foundation) for supporting my PhD program and the OpenLearn team for the opportunity to continue this research.

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Key Terms and Definitions

Argument and Evidence Map was first proposed by J.H. Wigmore in the early 1900s to help in the teaching and analysis of court cases. The objective is to expose the structure of an argument, in particular how evidence is being used, in order to clarify the status of the debate. Still used in legal education today, the idea has been extended, formalised (and reinvented) in many ways (Buckingham Shum, 2003; Reed et al., 2007), but all focused on elements such as *Claims, Evidence, Premises* and supporting/challenging relations.

Concept Map was developed by Joseph Novak around 1972, based on Ausubel's theory that meaningful learning only takes place when new concepts are connected to what is already known. Concept maps are hierarchical trees, in which concepts are connected with labelled, graphical links, most general at the top. Novak and many others have reported empirical evidence of the effectiveness of this technique, with an international conference dedicated to the approach.

Inquiry Map is a technique for knowledge visualization in academic research, which aims to facilitate the creation and communication of knowledge in inquiry projects through graphic representation. Beyond the mere transfer of facts, inquiry maps aim to further create or transfer insights, experiences, attitudes, values, interpretations, perspectives, understanding, and predictions by using various mapping techniques.

Issue Map or Dialogue Map derives from the "Issue-Based Information System" (IBIS) developed by Horst Rittel in the 1970s to scaffold groups tackling "wicked" socio-technical problems. IBIS structures deliberation by connecting *Issues, Positions and Arguments* in consistent ways, which can be rendered as textual outlines and graphical maps. "Dialogue Mapping" was developed by Conklin (2006) for using IBIS in meetings, extended as "Conversational Modelling" by Sierhuis and Selvin (1999) to integrate formal modelling and interoperability with other tools.

Mind Map was developed by Tony Buzan in the early 1970s when he published his popular book "*Use Your Head*." Mind Mapping requires the user to map keywords, sentences and pictures radiating from a central idea. The relatively low constraints on how elements can be labelled or linked makes it well suited for visual notetaking and brainstorming.

Open Learning is a learning method for the knowledge acquisition based on open educational resources, open source technologies and online communities. Open learning aims to allow pupils self-determined, independent and interest-guided learning. It has been also focussed on collaborative study and social learning.

Social Network refers to the acquisition of social competence that happens primarily in a social group, virtual learning environments or online communities. Social network depends on group dynamics, people with similar interests and disposition for interacting together.

Web Map appeared relatively recently as a result of the rapid growth of the internet. Software tools provide a way for users to capture, position, iconify, link and annotate hyperlinks in a visual space as they navigate, creating a richer trail which comes to have more personal meaning than a simple bookmark list.